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ABSTRACT

Science/Technology/Society STS) has been defined as teaching and learning in the context of human experiences. The STS movement has grown out of dissatisfaction with the curriculum reform of the 1960s and utilizes a problem solving approach that appeals to students' interests. This paper describes the STS approach and reports research results comparing STS and non-STS approaches to science instruction. The paper has six distinct purposes as follows: (1) to identify urgent problems related to school science teaching; (2) to describe how the STS approach can help solve these problems; (3) to describe the Iowa STS model and goals; (4) to give concrete examples of the use of STS in the classroom; (5) to report the results of four studies evaluating learning outcomes in STS courses; and (6) to identify some problems concerning the future use of STS. To meet these purposes, nine urgent problems related to the teaching and learning of science are identified and a discussion of how the STS approach would solve those problems is provided. Following this, a unique inservice teacher model to disseminate the STS approach called the Iowa Chatauqua Model is described. Five of the six major goals of this model are described in depth. Characterized as "domains," they are: (1) concept; (2) process; (3) applications; (4) creativity; and (5) attitude. The four studies assessing the impact of the STS approach on each of these domains are discussed next. The studies examined K-12 teachers (n=176) who had completed all aspects of the Iowa Chautauqua Program for 1988-89, and compared results of STS and non-STS students in grades 4-9 and student teachers in Taiwan. Results from the four studies indicated that no statistically significant differences were found in achievement in the concept domain. In the four other domains, strong differences were found in creativity and process domains for grades 4 and 5, in the application domain for grades 8 and 9, and for low ability students in the attitude domain. STS had a strong positive effect on the attitudes of females toward science. Finally, implications of these results in the areas of curriculum reform, assessment, STS, and the professional development of teachers are discussed and it is concluded that the four studies provide "hard" empirical evidence in favor of the STS approach for schoolchildren as well as for teachers. As regards purpose number 6, "problems," these are outlined very briefly in terms of activities considered to be important for future research. (Contains 33 references.) (MDH)

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THE STS APPROACH: REASONS, INTENTIONS, ACCOMPLISHMENTS AND OUTCOMES

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THE STS APPROACH: REASONS, INTENTIONS, ACCOMPLISHMENTS AND OUTCOMES

Abstract

The impact of the STS approach in four independent studies, (where three offer comparison between teaching STS and non-STS courses for a whole semester) are analyzed in five assessment domains. The studies feature an exceptionally strong design with replications and random assignment of treatments.

No statistically significant differences were found in achievement in the concept domain. On the other hand, unusually strong differences in favor of STS were found in the other four domains with effect sizes ranging between 1.62 and 3.21 standard deviations. The largest effect size in Creativity and in Process were found in grades 4 and 5 where grades 8 and 9 had the largest effect size in the Application Domain. Low ability students benefitted from STS, especially in the Attitude Domain. STS had a very strong positive effect on the attitudes of females toward science. The impact of experienced teachers is substantially stronger than that of novice teachers.

THE STS APPROACH: REASONS, INTENTIONS, ACCOMPLISHMENTS AND OUTCOMES

Introduction

The National Science Teachers Association (NSTA) defines Science/Technology/Society (STS) as teaching and learning science in the context of human experiences (1991). The STS movement has grown as a result of a general feeling of disappointment from the outcomes of the curriculum reform of the 1960's. It is important to realize that many of the basic ideas and goals of the 1960s have been adopted by STS. These include student growth in the processes of science, the nature of science, the concepts of science, and attitudes toward science. The main differences between the STS programs and the curricula of the 1960s are in the area of applications and use of knowledge, its relevance to the life of the individual and to society, and the role of the teacher in curriculum development. These three differences do not only represent different world views of science and knowledge, but can be regarded as a reaction to the curriculum theory which dominated the 1960s. It is based on the observation that most teachers have failed to effect the potential of the excellent curricula and continued their traditional instruction even with the new materials.

The notion of inquiry which was central to most of the major 1960's curricula has not been operationalized by most teachers. One reason for its under-use in aiding in the realization of new curriculum potential has been the centralistic approach to curriculum development which dominated the field in the 1960s According to this approach, the role of the teacher is to use the prescribed materials with high fidelity. Most teachers were not aware of the considerations of the developers and, consequently, felt like pawns in a chess game who are moved from one place to another with no way of influencing the direction of this movement. Closely related is the notion of relevance. In the 1960s it was assumed that if we taught the structure of the discipline and emphasized inquiry, students would not only learn the content and inquiry skills, but would use and apply them to everyday life and to problem-solving in general. When this happens, continued that

reasoning, positive attitudes toward science and science learning would follow. What actually happened, however, was that since the curricular potential has, by and large, not materialized, the whole train of expected events has not occurred. Classes have remained boring, rote learning continued to flourish, and many students have been alienated from science, most notably females and minorities. The STS approach, on the other hand, starts with the students, with their interests, and with what is relevant to their lives. It builds on local resources and it has assigned to the teachers the role of the major decision-maker regarding the curriculum and the instructional approach.

Purpose

The purposes of this article are:

1. To identify the urgent problems related to the teaching and learning of science in our schools.
2. To describe how the STS approach can offer solutions to many of these problems.
3. To describe the Iowa STS model and goals.
4. To characterize and give concrete examples of using the STS approach in the classroom.
5. To report results of four studies which have assessed the outcomes of learning in STS courses.
6. To identify some problems concerning the future use of STS in schools.

Methods

The first two purposes will be met through analysis of science education literature and through observations of the authors. The third and fourth purposes will be reached by providing a selection of teachers' descriptions of their work with their students. The fifth purpose will be achieved by re-analyzing and summarizing results of four recent studies which were carried out at the University of Iowa. The achievement of the final purpose will be based on the findings related to the purposes above.

Urgent Problems of Science Teaching

The following are some major problems that are frequently found in relation to science teaching:

1. Most students elect to quit study of science as soon as they are permitted to do so.
2. Students in science classes are more interested in and more knowledgeable about technology than they are about basic science concepts and processes.
3. Although a focus on science process skills (inquiry, critical thinking, problem-solving) has been the intention of science education reformers for more than 70 years, there is virtually no evidence that typical science courses have been successful in stimulating growth across grade levels in student mastery of such skills.
4. Although curiosity is the starting point for science (and technology), typical school science programs destroy natural curiosity. The longer students study in school, the less curious they are about the natural world.
5. Dealing with cause-and-effect relationships is basic to the scientific enterprise. Again, however, students who enroll in more science courses are not more logical in real-life situations than other students.
6. For many, knowing is the ability to use the concepts and processes practices, repeated, and tested in typical science classes in new situations. Unfortunately it is rare to find a student who can use science elsewhere after mastering concepts and process skills in science classrooms.
7. Newspaper reports and summaries of special studies have provided ample evidence of common misconceptions that students have about the natural world. These misconceptions are held by most students--even those enrolled in advanced college-preparatory courses.
8. Nearly all students see most of the science they study in school as unrelated to their daily lives.

9. Science study seems to most students to be unrelated to the world of work. They do not see science study as providing information or skills that are useful in making decisions required at work or in the community. In addition, they see few ties between the science they study and such personal concerns as their diets, hobbies, work experiences, and consumer decisions.

How the STS Approach Purports to Solve the Problems

STS has been characterized by ten features which have the potential of solving some of the problems mentioned above (NSTA, 1990). These include:

* using student identified problems with local interest and scientific and technical components as organizers for the course.
* using local resources (human and material) as original sources of scientific or technical information that can be used in problem resolution.
* involving students in seeking scientific or technical information that can be applied in solving real-life problems.
* extending science learning beyond the class period, the classroom, and the school.
* focusing on the impact of science and technology on each individual students.
* viewing science content as more than something that exists for students to master for tests.
* de-emphasizing the acquisition of science process, merely to mimic skills used by practicing scientists.
* emphasizing career awareness--especially careers related to science and technology.
* providing opportunities for students to perform in citizenship roles as they attempt to answer questions about the natural world and to deal with problems they have identified.
* demonstrating that science and technology are major factors with strong impact on the future.

STS is as an approach to science teaching that responds to each of the nine fundamental problems listed earlier. STS educators attempt to make school science more like science in the real

world. The content arises from human experience, either brought by students to the classroom or through situations stimulated by the teacher. It is not a prescribed set of concepts and activities that all are forced to experience. Instruction in typical classes (especially advanced high school and college classrooms) must be changed to include student experiences, questions, explanations, and tests in nature.

George Gaylord Simpson has posited three basic ingredients of science--all of which are missing in most K-12 and college classrooms. These include students 1) asking questions (about things in the world around them); 2) forming explanations (that is, possible answers to their questions); and 3) devising and carrying out tests to validate their own explanations (in contrast to verification-type laboratories found more than 90% of the time). These ingredients of science are basic to STS instruction. The concepts and process skills ordinarily used to plan instruction become the results of the scientific enterprise--not the starting points. STS proponents aim to stimulate the learning of all concepts and processes possible. They define "learning" as evidence that students can do something with the concepts and processes. It is using them that shows real evidence that they have been mastered.

STS advocates accept, respect, and encourage the learning of every science concept and process. They will readily accept the "core" ideas such as those advanced by Project 2061 or the SS&C Project as desirable goals. They refrain, however, from advocating the identification of such concepts as organizers for the teaching program. They doubt that this is a valid way to predict the likely future importance of science concepts and processes for all; they doubt that scientists, teachers, parents, and others can determine with any certainty what all must know.

Instead, STS proponents argue that natural curiosity, a facilitative teacher, discrepant events, current situations/news, and the social structure of schools and classrooms can be used to achieve mastery of important concepts and processes because of their use by students--not because of the efforts of teachers, scientist experts, or curriculum developers.

This does not suggest that teachers sit idly until students suddenly want to learn; instead they are anxiously and enthusiastically trying to encourage all students to question and to be involved. This encouragement and action can provide a reason for knowing. If a list of "vital" constructs of science is identified and accepted, STS proponents will work to provide a setting (context) that will assist students in using such constructs in a real-world situation (human experience). When students internalize learning in such a way, it seems to last. It arises from their experience in the real world. As a result, it can be used anew in the real world where students will live and work most of their lives.

According to NSTA (1990) the major purpose of STS is to produce graduates who are scientifically literate. NSTA has described such persons as those who:

* use concepts of science and of technology as well as an informed reflection of ethical values in solving everyday problems and making responsible decision in everyday life, including work and leisure;
* engage in responsible personal and civic actions after weighing the possible consequence of alternative options;
* defend decisions and actions using rational arguments based on evidence;
* engage in science and technology for the excitement and the explanations they provide;
* display curiosity about and appreciation of the natural and human-made world;
* apply skepticism, careful methods, logical reasoning, and creativity in investigating the observable universe;
* value scientific research and technological problem solving;
* locate, collect, analyze, and evaluate sources of scientific and technological information and uses these sources in solving problems, making decisions, and taking actions;
* distinguish between scientific and technological evidence and personal opinion and between reliable and unreliable information;
* remain open to new evidence and the tentativeness of scientific/technological knowledge;

* recognize that science and technology are human endeavors;
* weight the benefits and burdens of science and technological development;
* recognize the strengths and limitations of science and technology for advancing human welfare;
* analyze interactions among science, technology, and society;
* connect science and technology to other human endeavors, e.g., history, mathematics, the arts, and the humanities;
* consider the political, economic, moral, and ethical aspects of science and technology as they relate to personal and global issues; and
* offer explanations of natural phenomena which may be tested for their validity.

The Iowa STS Dissemination Model

A unique model of disseminating the STS approach has been developed at the University of Iowa. This model, known as the Iowa Chautauqua Model, has operated in Iowa since its inception in 1983. It was one of 20 state efforts funded by the National Science Foundation (NSF) as an experimental project proposed and coordinated by the National Science Teachers Association (NSTA). The original "National Chautauqua" was funded for a three-year period to determine its effectiveness as an efficient model for improving school science programs and teaching.

In 1984 the Iowa Utility Association sought to expand the program with their funds. This (and subsequent Eisenhower summer projects) provided a mechanism for supporting 30 to 50 teachers at each of five geographical sites in Iowa each year. The original NSF/NSTA project supported 30 teachers for each of the three years, 1983-86. With the expansion of numbers and sites, the Iowa Chautauqua Program has now enrolled over 1,800 K-12 teachers during the eight years of operation. (For the past three years the program has enrolled about 225 teachers each year.)

The Iowa Chautauqua Model has been described with several specific features (Blunck & Yager, 1990). In chronological order these include:

1. a two-week leadership conference for 25 of the most successful teachers from previous years who want to become a part of the instructional team for future workshops;
2. a two-week summer workshop at each new site for 30 new teachers electing to try Science/Technology/Society (STS) modules and strategies; the workshop provides experience with STS (teachers as students) and time to plan a five-day STS unit to be used with students in the fall;
3. a two and one-half day fall short course for 30-50 teachers (including the 30 enrolled during the summer); the focus is upon developing a month-long STS module and an extensive assessment plan;
4. interim communication with central staff, lead teachers, and fellow participants, including a newsletter, special memoranda, monthly telephone contacts, and school/classroom visits;
5. a two and one-half day spring short course for the same 30-50 teachers who participated in the fall; this session focuses upon reports by participants on their STS experience and the results of the assessment program.

The work with the teachers intends to help them teach toward achieving six major goals. These goals, which may be characterized as "domains," include: Concepts, Process, Applications, Creativity, Attitude, and the Nature of Science. The first five of these domains have been described by Yager and McCormack (1989).

Concept Domain

Science aims to categorize the observable universe into manageable units for study and to describe physical and biological relationships. Ultimately, science aims to provide reasonable explanations for observed relationships. Part of any science instruction involves student learning of the concepts central to science. Certainly student understanding of current explanations of objects and events in the universe is important, particularly when students can also use such concepts they have learned.

The Concept Domain includes: facts, information, concepts, laws, principles, existing explanations and theories being used by scientists.

Process Domain

How scientists think and work represents another dimension of science. Sometimes critical thinking is equated with scientific thinking. However, there are definable processes that characterize human actions that result in new knowledge of the universe. Generally these processes are embodied in the terms exploring and investigating. Processes of science identified by the American Association for the Advancement of Science (AAAS) in the development of *Science: A Process Approach* represent a generally accepted set of processes scientists use. They can be targets for instruction themselves. The 13 processes identified by AAAS (1963) include: observing; using space/time relationships; classifying; grouping and organizing; using numbers; quantifying; measuring; communicating; inferring; predicting; controlling and identifying variables; interpratating data; formulating hypotheses; defining operationally; and experimenting.

Certainly it is the hope that these processes can have applicability for all learners. To "know" the processes means being able to use them in a wide variety of situations. School science often fails to enable students to demonstrate such use. In traditional classrooms such skills are often the target of specific lessons, too often with no concern for the STS advocated personal use of such skills in new situations.

Applications Domain

It seems pointless to have a science program which does not include a substantial amount of information, skills, and attitudes that can be transferred and used in students' everyday lives. Also it seems inappropriate to divorce "pure" or "academic" science from technology. Students need to become sensitized to those experiences they encounter that reflect ideas they have learned in school science. Some dimensions of this domain are: seeing instances of scientific concepts in everyday life experiences; applying concepts and skills to everyday problems; understanding scientific and technological principles involved in household devices; using scientific processes in

solving problems that occur in everyday life; understanding and evaluating mass media reports of scientific developments; making decisions related to personal health, nutrition, and life style based on knowledge of scientific concepts rather than on "hear-say" or emotions; integrating science with other subjects; taking specific actions designed to resolve problems and/or contribute to the improvement of local, regional, national, and/or international problems; becoming involved in community-action projects; extending school experiences beyond the classroom; and emphasizing the interrelationships and interconnectedness of science to other human enterprises.

To be meaningful the material in science courses should be related to real life situations. For many this means focusing on technologies that are applications of science. Such applications also provide connections and serve as a means of enhancing creativity and attitude. When these are enhanced, more persons will see the value of processes and concepts and will advance to these commonly emphasized domains because they realize their relevance rather than accept the teacher assertion that they will be useful in the future.

Creativity Domain

Most science programs view science as something to be done to students to help them learn a given body of information. Little formal attention has been given in science programs to the development of students' imagination and creativity thinking. Scientists themselves frequently apply creative solutions to real problems. Therefore, it is reasonable for science educators to encourage the development and expansion of students' creative abilities. Some of the human abilities important in this domain include: visualizing--producing mental images; combining objects and ideas in new ways; producing alternative or unusual uses for objects; solving problems and puzzles; predict possible consequences; suggesting possible causes; designing devices and machines; producing unusual ideas; identifying; isolating; merging; diverging; and converging.

Much research and development has been conducted relative to the development of students' abilities in this domain, but very little has been incorporated into science programs. In fact, it is common for thinking of the arts and humanities relative to creativity--and not science.

Some of Torrance's (1966) work has focused upon questioning, identifying possible causes for a situation or event, and predicting consequence for a given happening. Creativity is involved with the quantity in each category as well as the quality and the uniqueness of the question, possible causes, or predicted consequences. Concern for student growth in these creativity areas is vital for teachers knowledgeable about the basic ingredients of science itself. STS by definition focuses on questions, causes for objects and events, consequences for certain actions or happenings.

Attitude Domain

In times of increasingly complex social and political institutions, environmental and energy problems, and anxiety about the future, scientific content, processes, applications, and even attention to creativity are not sufficient parameters for an exemplary science program. Human feelings, values, and decision-making skills need to be addressed as well. Science programs should exert positive influence on the development of more positive attitudes towards science, science courses, science learning, and science careers. This domain includes; developing positive attitudes toward science in general, science in school, and science teachers; developing positive attitudes towards oneself (an "I can do it" attitude); exploring human emotions; developing sensitivity to and respect for the feelings o other people; expressing personal feelings in a constructive way; making decisions about personal values; making decisions about social environmental issues; and exploring arguments on various sides of an issue.

It is generally accepted that all learning is enhanced when students have positive attitudes about the subject. They are more motivated, more involved with meeting the course objectives, and more likely to realize instructional goals. Negative attitudes discourage many and tend to make program goals trivial, even for those who wish generally to excel in school. The focus of STS upon current issues and student questions and interests makes the attitude domain particularly important.

The Nature of Scientific Enterprise Domain

This domain may be regarded as the theoretical and philosophical basis of the STS approach. It focuses on the nature of scientific knowledge, the processes of its development and the effects of social and political context on the process. Understanding the tentative character of scientific explanations and of notions such as "stable" versus "fluid" or "normal" versus "revolutionary," "paradigms," "models," "laws," and "theories" consist one focus of this domain. The role of professional journals, conferences, and research institutions are examples of other aspects which characterize the scientific enterprise.

STS in the Classroom

Table 1 presents some characteristics of the STS approach compared with traditional instruction.

Insert Table 1 here

Following are descriptions of activities in two STS courses, one given in the U.S. to students in grades 9 and the other taught in Taiwan to preservice student teachers.

An STS Course in Grade 9 (Myers, 1988)

Early in September the students identified several problems and issues concerning their locality. These issues were then discussed in class so that all students had some understanding of what the problems were, what some of their causes might be, some of the information known by class members, and some of the things no one knew or understood about the problems. The students were asked to consider some of the problem whose solutions were essential to maintaining or improving the quality of their lives not and in the future. Student responses were written on the blackboard with no teacher comment. All students were encouraged to contribute to the list. When a student had no contribution to make, they responded, "pass." When all students had no additional problems to identify, the brainstorming ceased.

Each listed problem was reviewed and, where possible, inter-related problems were combined in one listing. Student questions and comments were encouraged all during this phase of the procedure. Eventually the list was narrowed dow to several societal problems that had significance to the students. At this point in the procedure the students are permitted to lobby for or against any of the listings on the blackboard. Class consensus was relied upon to eliminate any problem from the list. Consensus was arrived at by asking students to vote for three problems they would wish to learn more about. The obvious "loosers" were eliminated form the list. By repetition of this procedure one problem was ultimately identified as the class project.

All during this sequence of steps the procedure remained highly students centered.

Once the subject of class investigation was determined by the students, they were then asked by the teacher to identify what they wished to learn about the problem. The questions were collected, organized, duplicated, and given to the students the following day. The organization of these questions allowed the teacher to determine what was on the minds of the students and allowed the identification of several focal points of the study unit.

The students were then asked how they would like to find out the answers to their concerns. Since these students had had very limited experiences of this type in the past, the teachers suggested several ways it would be possible to learn more about their identified problem. Field-trips, classroom speakers, library papers, textbook materials, laboratory experiences, and field experiences were some of the options provided to students. Students were told that arrangements for classroom speakers, field trips, and field experiences would be their responsibilities.

<u>An STS Course for Preservice Teachers</u> (Yager, Tamir & Huang, 1991)

The students worked in groups of four or five members each. Each group had to identify at least one personal, family, or societal problem related to the main theme of the unit. Group members worked together to propose ways to solve the problems identified. In the class each

group presented an oral report of his/her inquiry for each topic. Students were guided to address in their reports the following questions:

1. Why do you consider that the problem or issue identified is important?
2. What are some biological concepts, laws, and principles related to the problem or issue?
3. How will you resolve the problem or issue?
4. What basic biological concepts, laws, and principles are used in your strategies for resolving the problem or issue?
5. What difficulties did you encounter when you were taking actions for resolving the problem or issue?
6. What specific steps would you take as a next action for resolving the problem or issue?

If any lab work was necessary for group activities, then the specific lab work was designed and executed by the group. During all learning activities, the instructor acted as a supervisor rather than a provider of information.

The following is a part of an oral report given by a group as part of their study of Genetics. The report illustrates some basic characteristics of the STS approach such as involving the community, collecting relevant data, focusing on a socially important problem, dealing with controversial issues that require scientific understanding, and finally, trying to actually do something to help solve the problem.

<u>The Legal Issue of Sterilizing Down Syndrome Victims</u>

Recently, there was a hotly controversial issue in the newspapers about whether it is legitimate to sterilize Down's syndrome victims in terms of preventing pregnancy and other physiological disorder or social problems. Down's syndrome is one of the most common severe diseases, appearing about once in every 700 live births. In terms of probability, it is estimated that there are nearly 30,000 who suffer from the disease today in Taiwan! The problem is how to cut down on the frequency of more cases appearing.

Because the issue is related to the legal and medical professionals, we decided to interview the experts of those fields in order to gather their opinions and theories about how to resolve the issue. In addition, ideas from parents and child psychologists were also considered and should be collected. Based on all the information collected and the decision made in class discussion, we made a suggestion for how to resolve this controversial issue to the general public. Since over 70% of the data gathered from interviews agrees that the parents of the victims have to be responsible in taking care of the daily living of the victims, so, the parents ought to deserve a place in making a decision as to whether a sterilization operation ought to be done to their children.

Most of the lawyers interviewed opposed allowing the parents of Down's victims the right to make such a decision. They considered the sterilization operation as violating Criminal Law No. 10, Item 4. Therefore, the offender would be sentenced to prison for three years. This is the obstacle for most of the parents in asking a surgeon to do such an operation.

In order to tear down this obstacle, we decided to suggest to the Central Government a Eugenic Law making it legal for parents of Down's victims or other related cases to make a decision to do such an operation, thereby sterilizing them to prevent more such victims in future generations.

Four Evaluating Studies

As described above, the University of Iowa has been a very active center for dissemination and implementation of the STS approach. The model of long-term support for teachers was accompanied by evaluation and research. A package of assessment items for the Concept, Process, and Application Domains was compiled (McComas & Yager, 1988). Various existing instruments pertaining to the six domains identified as expect outcomes of an STS course and described above were used . Table 2 presents descriptive data regarding the four studies under consideration, including the instruments used.

Insert Table 2 here

Validity was ascertained by a panel of science educators especially for the teacher-created tests, but also for existing instruments as they pertain to the students participating in the studies. Reliability was established by test-retest, internal consistency, and inter-rater agreement.

Because of using a variety of lessons and students of different ages, different items were used by different teachers. However, all five domains were included. The instruments were taken from the *Iowa Assessment Package* (McComas & Yager, 1988). Only paper and pencil instruments were included.

The Concept Domain was assessed by multiple choice tests with test-retest reliabilities ranging from 0.76 to 0.81. A sample item was: Which of the following would most likely cause tooth decay by over eating? A) Carrot, B)Candy, C) Bread, D) Hamburger.

The Process Domain was represented by 13 skills advocated by the American Association for the Advancement of Science (AAAS) as follows: observing, using space/time relationships, classifying, graphing and organizing, using numbers, measuring, communicating, inferring, formulating hypotheses, predicting, interpreting data, controlling variables, defining operationally, and experimenting. More detailed definitions and examples of items belonging to each process may be found in Yager, Blunck, and Tamir (1991). The test-retest reliabilities of the process tests used in this study ranged between 0.82 and 0.90. A sample item was:
Which variable should be held constant in an experiment which measures the effect of exercise on the rate of respiration?

A) The temperature of the environment.

B) The body temperature of the subject.

C) The carbon dioxide concentration in the environment.

D) The carbon dioxide concentration in the blood of the subject.

The Attitude Domain was assessed by a collection of items from the National Assessment of Educational Process (NAEP, 1978). Eighteen likert-type items five point scale was used (Yager, Blunck & Ajam, 1990). Most studies of attitude with the NAEP items in typical classrooms reveal that student attitudes become more negative the longer students study science (Yager & Bonnstetter, 1984; Yager & Penick, 1984; Yager & Yager, 1985). Such information has been reported in each of the NAEP reports themselves: 1978, 1982, and 1987 (Hueftel, Rakow & Welch, 1983; NAEP, 1978, 1988).

The Application Domain was tested by multiple choice items focusing on possible uses of knowledge and skills in everyday life. Some dimensions of Applications are: solving everyday problems, understanding science and technological principles related to everyday life, maintaining critical positions related to advertising and commercials, and becoming involved in community action. It may be noted that because of the different contexts, every teacher used different application items. The test-retest reliabilities ranged from 0.79 to 0.83. A sample item was: Which of the following is the main reason that water should not be stored in the freezer in totally filled glass containers?

A) The taste of the water will change.

B) The glass container will break

C) The water reacts with glass in very low temperatures.

D) Lack of space will prevent the water from freezing.

The Creativity Domain is based on visualizing and imaging, combining ideas and objects in new ways, and identifying unique uses for certain objects. The average test-retest reliability for tests compiled by the teachers was 0.88. Sample questions were:

1. Describe what would happen in a world without gravity. Write down as many responses as you can which you believe are correct. Be as imaginative as you can.
2. In a visit to the zoo, you stop to observe an elephant. Write down as many questions as you can for which you may find answers by observing the elephant.

Study No. 1 (Yager, 1991)

A total of 176 K-12 teachers completed all aspects of the Iowa Chautauqua Program for 1988-89. Pre- and posttest assessment in concept mastery, skill with science processes, applications of science concepts, positive attitudes concerning school science and careers, and creativity skills revealed a preponderance of positive growth that would be unexpected in typical courses across the K-12 continuum. Studies by NAEP and other groups have generally reported school science to affect negative changes regarding attitude and creativity skills. Most studies have revealed that students who seem to know have no ability to use the information in other contexts. (Champagne & Klopfer, 1984; Mestre and Lockhead, 1990). Typical results of studies of learning in school science reveal that few can do anything with the skills and concepts taught outside the classroom/laboratory. The pre-posttest results reveal a major contrast to this general situation when STS strategies are employed even with first-time users of STS materials and strategies.

Study No. 2 (Yager, Tamir & Mackinnu, 1991)

The sample consisted of 15 experienced teachers who have had special expertise in using the Science-Technology-Society (STS) approach in teaching science. The teachers have been active "lead" teachers in their school districts and have participated for several years in the Iowa Chautauqua inservice teacher program. Hence, they were all familiar with the STS philosophy and with its advocated instructional strategies. Five taught grades 4 and 5, another five taught grades 6 and 7 and the remaining teachers taught grades 8 and 9. Each teacher selected two matched classes, one of which was randomly assigned to STS and the other to a textbook-based program designated as non-STS. Altogether, there were 30 classes and 720 students. The teachers agreed to do their best in each of the two classes trying to isolate the instructional approach and to keep constant all other variables, such as instructional time, homework, subject matter, and enthusiasm.

The results of the concept tests indicated that with the kind of teachers who participated in the study there were no statistically significant differences between STS and non-STS. The consistency of the results is quite impressive if one notes that different teachers administered

different test items related to the topic they taught (e.g., weather, radioactivity, etc.). It may be concluded that even though the STS approach follows the local interests and preferences of students, is much less structured and does not enjoy the benefit of textbook material that can easily be memorized, concept learning, knowledge, and understanding are as high as that of non-STS students. Apparently, the student centered STS activities result in more meaningful learning which is reflected in the performance on knowledge tests.

Insert Table 3 here

The data in Table 3 indicate that without losing in content learning STS students have gained substantially more than their non-STS counterparts in all four domains. The largest difference appeared in Applications followed by Process and Creativity and the smallest difference, which was still very high (1.6 standard deviations!) was found in Attitude.

Insert Table 4 here

The data in Table 4 show that the effect of the STS approach on Process and Creativity was largest in grades 4 and 5 whereas the affect on Applications increased with age and was largest in Grades 8 and 9. Although indicating change in attitude appeared to be more difficult than in the other three domains in all grade levels, it was most difficult in grades 8 and 9, probably because of the longer period of schooling which accounted for the development of negative attitudes toward science.

Students in each class were classified as high (above mean) or low (below mean) on the basis of their concept pretest scores. The high ability students have benefitted from STS substantially more than their lower ability counterparts in Process, Application, and Creativity, and

somewhat more in their Attitudes. The STS approach was especially effective in enhancing more positive attitudes in the low ability students.

Table 5 shows that in four domains females achieved somewhat better than males and that the difference in STS is very small, whereas in non-STS there are moderate differences. The Attitude domain is an exception.

Insert Table 5 here

It may be seen that in both non-STS and STS classes the attitudes of boys toward science was substantially more positive than those of girls. Following instruction, the gap between boys and girls decreased by 0.35 standard deviations in the non-STS classes--a positive but moderate effect. However in the STS classes, the positive effect on girls was very strong, close to three times as much as that in non-STS classes! It may be concluded that the STS approach has a strong potential for overcoming the decline in attitude toward science which has been especially prevalent among girls.

For some teachers the magnitude of attitude change was similar in STS and non-STS classes. However, for most teachers the STS approach was much more effective. For one teacher, the non-STS class showed a negative impact on girls whereas the matching STS class had a positive change of 1.24 effect size units! In grades 4 and 5 the average change of the five non-STS classes amounted to 0.15 whereas that of the STS reached 0.49 effect size units. In grades 6 and 7, the corresponding figures were 0.42 and 1.02, whereas in grades 8 and 9 they were 0.37 and 1.12 respectively. It may be concluded that the impact of STS on girls was somewhat lower in grades 6 and 7 than in either the lower or higher grades.

Study No. 3 (Myers, 1988)

This study involved four classes and 116 students. Table 6 presents the results comparing the performance of STS and non-STS students in grade 9 on five measures.

Insert Table 6 here

It may be seen that the highest gain was evident in the Concept Domain. In addition, whereas the STS course resulted in an average gain of 22% in the attitude toward science, the non-STS course resulted in an average decline of 2%. A breakdown of the Creativity results revealed that the greatest effect sizes and growth occurred in providing pertinent predictions, causes, and questions, while the smallest were found in the uniqueness of the responses. It may be concluded that an STS approach in grade 9 can bring about significant gains and growth in learning outcomes.

Study No. 4 (Yager, Tamir, and Huang, 1991)

This study involved four classes of student teachers in Taiwan; two following an STS and two a non-STS biology course. Table 7 presents the growth of STS compared with non-STS in five domains and Table 8 the effect sizes for each of these domains in Studies 2, 3, and 4. The data in Table 7 indicate that there were practically no differences between STS and non-STS student teachers in concept learning. On the remaining four measures, the gain of STS students was roughly twice as that of non-STS student teachers.

The data in Table 7 indicate that the growth of elementary, junior high, and senior high students who studied from experienced STS teachers (Study No. 2) was much greater than that of STS 9th graders (with the exception of creativity) who studied from a less experience teacher. Similarly, the growth of the students in Study No. 2 was much larger than that of the student teachers (Study No. 4). On the other hand, the growth figures in Studies 3 and 4 are more similar with one conspicuous difference pertaining to Creativity where the 9th grade scores was four times higher than that of student teachers.

The effect sizes in Table 8 help to see more clearly the similarities and differences among the populations in the three studies. The distinctiveness of the results in Study No. 2 may be clearly observed.

Insert Tables 7 and 8 here

Discussion

Although the STS approach has been gaining increasing support among science educators (e.g., Bybee, 1987, Hurd, 1984; NSTA, 1982), very little empirical support for this approach can be found in the literature. As early as the 1960s and 1970s serious reservations have been raised from studies which compare Method A with Method B in terms of results of achievement tests (Cronbach, 1964; Shulman & Tamir, 1973). Among the major arguments against such comparisons are included the difficulty of establishing identical conditions other than the tested curriculum and/or instructional strategy, the inadequacy of outcome measures, the Hawthorn effect and the unknown effect of teachers that may mask the impact of particular programs. The present studies seem to have successfully overcome many of the potential limitations of a comparative study. First the teachers in Studies No. 2 and 4 were highly select. They have had years of experience with STS, hence the danger of the Hawthorn effect was eliminated. Being experienced teachers who agreed to play the game correctly they succeeded to provide high quality instruction to the non-STS classes as well as to the STS ones. This assertion is based on visitations to classes and on informal feedback from the teachers and their principals. At the same time most convincing are the results which indicate no statistically significant differences in achievement in the Concept Domain. A high quality instruction, whether STS or not, yields almost identical gains in content knowledge. With this as a background as well as the consistency of results across studies, a high level of confidence may be given to the results in the remaining four domains.

The unique nature of Study No. 2 offers even more support to the confidence in the results. It is very rare to find in the educational literature studies which feature 15 replications and in which an absolute random assignment to the two treatments has taken place. The design included three age groups with five teachers teaching each of them. This allowed the researcher to note results which were common to all age groups as well as differences among these groups. The participation of different grade levels and the student centered nature of the STS approach did not allow for teaching identical topics to all classes. In fact, every teacher followed his or her own topics. The only matching was that between the two classes of the sam teachers. This setting unavoidably implied the use of different test items by each teacher in all the domains except the Attitude Domain. Consequently, results which were common to all or many teachers, in spite of differences in content and specific activities, may be regarded as reflecting the generic impact of the STS approach. The basic consistency of results across studies permits even more confidence. With this high level of confidence let us summarize the major findings:

1. With experienced high-quality teachers the STS approach yields neither better nor worse attainment in the Concept Domain.
2. In all the remaining domains ,the STS approach was found to yield substantially better results. The effect size differences between STS and non-STS are unusually high.
3. The largest effect sizes in Creativity and in the Process of Science were found in Study No. 2 in grades 4 and 5. Creativity was very high in grade 9 in Study No. 3. This may imply that special attention should be given to these domains at these age levels by providing adequate opportunities and experiences.
4. The ability to apply has had the highest effect size in grades 8 and 9. Apparently, transfer of learning has better chances in older students who have had more experiences in more contexts in their lives.

5. High ability students have gained more than their low ability counterparts in all domains regardless of the instructional approach. For low ability students, the STS approach yielded more positive attitudes toward science and science learning.

6. The only domain in which gender differences were found was Attitudes. Thus while positive attitude changes of girls were found in both treatments, the STS yielded a positive change close to three times as large as the non-STS.

It should be stressed again that the teachers in Study No. 2 were very special. Students of less experienced and less trained, such as those in Study No. 1 will not reach such a high level. However, the results of Study No. 2 certainly reflect and provide strong evidence for the high potential of the STS approach. The results of the three other studies indicate that positive results can be obtained even with less experienced teachers.

Implications

The findings and conclusions reported in this article have important implications in four areas, namely curriculum reform, assessment, Science/Technology/Society, and the professional development of teachers.

Curriculum Reform

There exists a general consensus in the U.S.A. that most curriculum reforms and especially those initiated and supported by NSF in the 1960s have fallen quite short of the high expectations of all involved, namely, students, teachers, college professors, the general public, and the funding agencies. And, yet, many examples of exemplary teaching have been found through the NSTA initiated study (Yager & Penick, 1984). These exemplary teachers provided evidence that the problem of unsuccessful use of innovative programs is not the nature of the curriculum materials but rather the failure of teachers and schools to effect the potential of the curriculum. If some teachers could do it, efforts should attempt to create such conditions that many more teachers would be able to do it as well. Here is where the U.S. may learn from other countries, such as Israel or Thailand. These countries recognized as early as the 1960s that curriculum development

and implementation would be a long term mission which would require continuous support and which evolves slowly, based on interaction among curricular specialists, teachers, students, principals, communities, and evaluators. In order to maintain the continuity of support, special long term projects have been established in several countries. For example, the Israel Science Teaching Center which was founded in 1967 has been operating ever since curriculum development and implementation projects in biology, chemistry, physics, elementary science, computer aided instruction, environmental education, earth science, and more.

The projects have been located in universities and directed by science educators thereby providing expertise, leadership, evaluation, and research. They have worked in close cooperation with various personnel in the Ministry of Education, such as supervisors, the Examination Department, and the Inservice Teacher Education Department. They have established special services, such as the Supply Center for high school biology to which schools pay a small annual subscription ($100.00) and are entitled to unlimited supplies of organisms and chemicals necessary for the laboratory investigations as well as loan service of films and video tapes.

Strong ties have been maintained between the project's staff and the teachers through various means such as regular inservice activities which take place every Tuesday, a Biology Teachers Bulletin published three to four times a year, and the matriculation examinations which are set and assessed with substantial collaboration among the teachers, the Ministry of Education, and the project staff. More details about the Israel High School Biology Project may be found in various publications (e.g., Tamir, 1976, 1985).

The Science Education Center at the University of Iowa is perhaps the only place in the U.S.A. which has been operating in a manner that features many of the successful strategies of national centers such as the Israel Science Teaching Center as described.

Assessment

One of the reasons that innovative programs of the 1960s have failed to show positive effects was the measures used in evaluation which was often standard multiple choice tests or

general critical thinking or attitude measuring instruments which have not allowed demonstration of the unique contributions of a particular program. In the few cases where authentic assessment has been used, substantial differences in favor of the innovative programs have been found in performance in the laboratory (Tamir, 1974) or in the effect of the high school learning on learning and achievement in the university (Tamir & Amir, 1981). In the efforts to assess the impact of the STS approach an evaluation profile has been created which represents the desired outcomes in six domains, namely, Concept, Process, Application, Attitude, Creativity, and "Understanding the Nature of Science" (Tamir, Yager, Kellerman & Blunck, 1991).

The results of this study show that the area where the impact of the STS approach has been smallest is the Concept Domain which, of course, has been the focus of traditional assessment. Results of many studies have shown that ordinary paper and pencil achievement tests are not as sensitive to the efforts of instructional approaches as other outcome measures such as attitudes, performance of problem solving in the laboratory, or application tasks (e.g., Comber & Keeves, 1973; Shulman & Tamir, 1973; Tamir, 1988). The lack of differences in the Concept Domain between STS and non-STS students of the lead teachers indicates that good teachers provide meaningful learning regardless of the specific approach they employ. On the other hand, if no opportunity is offered to be creative or to apply, the performance in these domains would be significantly adversely affected. It may be concluded that in selecting outcomes and instruments for curriculum evaluation, serious consideration and attention should be given to the assessment domains. Thus, not to assess attitude or creativity because no perfect instruments are available would be a mistake. The goals and activities of a curriculum should be the primary criterion for selecting and developing means of assessment. Validity should be never sacrificed in the service of increasing either reliability or objectivity of measurement.

Science/Technology/Society

Although many of the claims put forward by STS proponents appear to make sense, very little research has been done to test the validity of these claims empirically. Wisenmayer & Rubba

(1990) found a positive effect of STS on content knowledge, on skills used in investigating STS issues as well as knowledge about citizenship and the science technology and society interactions.

Kahle (1985) suggests that an STS approach which builds on life experiences and emphasizes humanistic and socially relevant activities would be especially beneficial to females who tend to shy away from traditional science courses. Bybee (1987) surveyed the view of science educators and found a general support for the STS theme as a part of the science curriculum.

The four studies described here provide "hard" empirical evidence in favor of the STS approach for school children of various ages as well as for teachers. The effect sizes are unusually high, a result which supports the efforts to disseminate and implement the STS approach among science teachers of all ages.

The Professional Development of Teachers

The Iowa model of teacher education known as the Iowa Chautauqua Model has been described in the introduction of this paper. The most conspicuous features of this program are:

1. The continuity over more than ten years.
2. The involvement of "lead" teachers who have gained experience in STS teaching and who can communicate effectively with novice teachers.
3. The encouragement of participating teachers to be engaged in curriculum development and the provision of necessary support.
4. The responsive atmosphere of project staff to needs of both the "lead" teachers and the novices.
5. The readiness to modify, add, and delete various activities on the basis of experience and the results of formative evaluation.

Some Problems Concerning Future Use of STS in Schools

In light of the results obtained in the studies reported in this article, the following activities are considered to be important for future research:

1. Finding to what extent is the strong development of evaluation instruments representing a variety of modes of performance in the six domains.
2. Determining how consistent the professional development of teachers as a function of their involvement in STS.
3. Describing what successful STS teachers do in the development of adequate tests for STS issues as well as in the analysis and interpretation of test results.
4. Developing alternative assessment procedures such as self-assessment and portfolios.
5. Determining the strength and consistency of the finding about the strong effect of STS on girls' attitude toward science generalizable.
6. Studying the consistency of the gains in the various domains across grade levels.
7. Determining what successful STS teachers do in proactive, interactive, and reflective phases of teaching.

REFERENCES

American Association for the Advancement of Science. (1963). Science--A process approach. Washington, DC: Ginn & Co.

Blunck, S. M., & Yager, R. E. (1990). The Iowa Chautauqua Program: A model for improving science in the elementary school. Journal of Elementary Science Education, 2(2), 3-9.

Bybee, R. (1987). Science education and the science/technology/society (STS) theme. Science Education, 71, 667-683.

Champagne, A. B., & Klopfer, L. E. (1984). Research in science education: The cognitive psychology perspective. In D. Holdzkom & P. B. Lutz, (Eds.), Research within reach: Science education (pp. 171-189). Charleston, WV: Research and Development Interpretation Service.

Comber, L. C., & Keeves, J. E. (1973). Science education in seventeen countries.

Cronbach, L. (1964). Course improvement through evaluation. The Teachers College Record, 64, 672-683.

Fraser, B. J. (1981). Test of science-related attitudes. Victoria, Australia: The Australian Council for Educational Research Limited.

Hueftle, S. J., Rakow, S. J., & Welch, W. W. (1983). Images of science: A summary of results from the 1981-82 national assessment in science. Minneapolis, MN: The University of Minnesota, Minnesota Research and Evaluation Center.

Hurd, P. DeH. (1984). Reforming science education: The search for a new visions, (Occasional Paper 33). Washington, DC: Council for Basic Education.

Kahle, J. B. (1985). Women biologists: A view and vision. BioScience, 35, 230-234.

Mestre, J. P., & Lockhead, J. (1990). Academic preparation in science: Teaching for transition from high school to college. New York, NY: College Entrance Examination Board.

Myers, L. H. (1988). Analysis of student outcomes in ninth grade physical science taught with a science/technology/society focus versus one taught with a textbook orientation. Unpublished doctoral dissertation, The University of Iowa, IA.

National Assessment of Educational Progress. (1978). The third assessment of science, 1967-77. Denver, CO: Author.

National Assessment of Educational Progress. (1988). The science report card: Elements of rise and recovery. Princeton, NJ: Educational Testing Service.

National Science Teachers Association. (1991, April). Science/technology/society: A new effort for providing appropriate science for all (The NSTA position statement). NSTA Reports!, pp 36-37.

Shulman, L. S., & Tamir, P. (1973). Research on teaching in the natural sciences. In R. M. W. Travers (Ed.), Second Handbook of Research on Teaching (pp. 1098-1148). Chicago, IL: Rand McNally.

Tamir, P. (1974). An inquiry oriented laboratory examination. Journal of Educational Measurement. 11, 25-33.

Tamir, P. (1976). The Israeli high school biology--A case of curriculum adaptation. Curriculum Theory Network, 5, 305-315.

Tamir, P. (1985). The Israeli "Bagrut" examination in biology revisited. Journal of Research in Science Teaching, 22(1), 31-40.

Tamir, P. (1988). Fostering the scientific potential of Israel in the light of the second international science study. Jerusalem, Israel: Ministry of Science Development.

Tamir, P., & Amir, R. (1981). Retrospective curriculum evaluation: An approach to evaluation of long term effects. Curriculum Inquiry, 11, 259-274.

Tamir, P., Yager, R. E., Kellerman, L., & Blunck, S. M. (1991). The Iowa assessment handbook. Iowa City, IA: The University of Iowa, Science Education Center.

Torrance, P. E. (1966). Torrance test of creative thinking. Princeton, NJ: Personnel Press, Inc.

Welch, W. W. (1969). Wisconsin inventory of science processes (WISP). Madison, WI: The University of Wisconsin, Scientific Literacy Research Center.

Wiesenmayer, R. L., & Rubba, P. A. (1990, April). The effects of STS issue in issue investigation and action instruction and traditional life science instruction on seventh grade students' citizenship behaviors. Paper presented at the Annual Convention of the National Association for Research in Science Teaching, Atlanta, GA.

Yager, R. E. (1991). The constructivist learning model: Towards real reform in science education. The Science Teacher, 58(6), 52-57.

Yager, R. E., Blunck, S. M., &Ajam, M. (Eds.). (1990). The Iowa assessment package for evaluation in five domains of science education (2nd ed.). Iowa City, IA: The University of Iowa, Science Education Center.

Yager, R. E., & Bonnstetter, R. J. (1984). Student perceptions of science teachers, classes, and course content. School Science and Mathematics, 84(5), 406-414.

Yager, R. E., & Penick, J. E. (1984). What students say about science teaching and science teachers. Science Education, 68(2), 143-152.

Yager, R. E., Tamir, P., & Mackinnu. (1991). The effect of an STS approach on achievement and attitudes of students in grades 4 through 9. Manuscript submitted for publication.

Yager, R. E., & McCormack, A. J. (1989). Assessing teaching/learning successes in multiple domains of science and science education. Science Education, 73(1), 45-58.

Yager, R. E., Tamir, P., & Huang, D. S. (1991). The effect of an STS approach to human biology on achievement and attitudes of elementary science majors. Unpublished manuscript.

Yager, R. E., & Yager, S. O. (1985). Changes in perceptions of science for third, seventh, and eleventh grade students. Journal of Research in Science Teaching, 22(4), 347-358.

Table 1

Some Characteristics of STS and Traditional Instruction Approaches

STS	Traditional
Student-centered.	Teacher-centered.
Individualized and personalized, recognizing student diversity.	Group instruction geared for the average student.
Uses a variety of resources.	Directed by the textbook.
Cooperative work on problems and issues.	Some group work, primarily in laboratory.
Students are considered active contributors to instruction.	Students seen as recipients of instruction.
Teachers build on student experiences, assuming that students learn best from their own experiences.	Teachers do not build on students experiences, assuming that students learn more efficiently by being presented with organized easy to grasp information.
Teachers plan their teaching around problems and current issues.	Teachers plan their teaching from prescribed curriculum guides and textbooks.

Table 2

Descriptive Data on the Four Studies

Study Number	1	2	3	4
Authors	Yager, 1991	Yager, Tamir & Mackinnu, 1991	Myers, 1988	Yager, Tamir & Huang, 1991
Grade Level	K-12	4-9	9	Student teachers
Number of STS classes	176	15	2	2
Number of Non-STS classes	0	15	2	2
Number of teachers	176	15	2	2
Instruments used: Concept	Teacher-made test	Iowa package	ITBS Science	50 multiple choice items
Process	Iowa package	Iowa package	ITBS Science	SPI
Application	Teacher-made test	NAEP (Iowa)	NAEP (Iowa)	50 multiple choice items
Attitude	NAEP (Iowa)	NAEP (Iowa)	NAEP (Iowa)	TOSA, NAEP (Iowa)
Creativity	Questions, Causes, Consequences	"Imagine what would happen if..."	"Imagine what would happen if..."	Questions, Causes, Consequences

Iowa Package: Concept, Process, and Application items (Yager & McCormack, 1989).

ITBS: Iowa Test of Basic Skills - Science Subtest (1987), contains 45 items.

SPI: Science Process Inventory (Welch, 1969) measures understanding of the process of science.

TOSA: Test of Science Related Attitudes (Fraser, 1981).

NAEP (Iowa): Items selected from the National Assessment of Educational Progress (1978).

Questions, Causes, Consequences: Presented with a thought-provoking situation, students are asked to formulate questions, guess possible causes, and predict possible consequences. Scoring is based on the number of ideas, their pertinence, and their uniqueness.

Table 3

Average Posttest Scores, Standard Deviations, and
Effect Sizes of Non-STS and STS Students in Five Domains

(N = 15 pairs of classes)

Domain	Non-STS $\bar{X}$	Non-STS S.D.	STS $\bar{X}$	STS S.D.	Average t	Average Effect Size	Average S.E.
Concept	11.80	3.00	11.71	3.00	0.61	0.03	0.07
Process	4.20	1.97	8.83	2.43	6.90*	2.20	0.10
Application	4.30	1.99	11.20	2.89	9.38*	3.21	0.12
Creativity	61.47	23.27	103.43	30.43	6.21*	2.12	0.10
Attitude	13.42	4.02	20.0	3.90	5.75*	1.62	0.09

Average N per class = 24 students

* $p < 0.001$

Table 4

Difference in Effects by Grade Level

(in effect size units)

Domain	Grades 4-5 N = 5	Grades 6-7 N = 5	Grades 8-9 N = 5
Process	2.57	2.20	2.26
Application	3.03	3.63	4.30
Creativity	3.23	1.91	1.96
Attitude	1.70	1.79	1.55

Table 5

Gender Differences in Performance of STS and Non-STS Students in Five Domains

(in effect size units)

Domain	Non-STS			STS		
	Pretest	Posttest	Change	Pretest	Posttest	Change
Concept	0.42	0.42	0.00	0.19	0.20	0.01
Process	0.48	0.51	0.03	0.20	0.20	0.00
Application	0.40	0.42	0.02	0.20	0.22	0.02
Creativity	0.51	0.50	0.01	0.30	0.35	0.05
Attitude	-0.75	-0.40	0.35	-1.15	-0.25	0.90

- Male higher score

Table 6

Mean Posttest Scores, Standard Deviations, and Effect Sizes of Non-STS and STS Students in Five Domains

Domain	Non-STS N = 59 $\bar{X}$	Non-STS N = 59 S.D.	STS N = 57 $\bar{X}$	STS N = 57 S.D.	t	Effect Size	Growth Non-STS	Growth STS
Concept	29.82	4.06	31.44	3.74	2.27*	0.40	2.46	2.52
Nature of Science	105.00	5.20	108.46	5.24	3.56*	0.67	0.67	1.64
Application	33.14	3.51	35.79	2.88	4.46**	0.75	0.65	1.56
Creativity	46.43	19.76	57.22	19.42	3.15**	0.55	0.36	0.77
Scientific Attitude	23.44	2.57	25.72	3.02	4.37**	0.89	0.76	1.46

* $p < 0.05$
** $p < 0.01$

Table 7

Growth and Progress Made by Students
Who Study Different Non-STS and STS Courses

Study/Group	N	Concept	Process	Application	Attitude	Creativity
Non-STS						
2 Elementary	5)					
2 Middle	5)	6.30	1.25	2.05	-0.10	0.25
2 Junior High	5)					
3 Ninth Grade	2	0.18	0.11	0.15	0.12	0.60
4 Student Teachers	2	2.46	0.67	0.65	0.76	0.36
STS						
1 K-12	176	+	+	+	+	0.41
2 Elementary	5)					
2 Middle	5)	5.45	5.55	8.55	2.00	7.50
2 Junior High	5)					
3 Ninth Grade	2	0.23	0.72	0.98	0.67	3.61
4 Student Teachers	2	2.52	1.64	1.56	1.46	0.89

N = Number of Teachers
+ = Available data do not permit calculation of the growth index.
Elementary = Grades 4 and 5
Middle = Grades 6 and 7
Junior High = Grades 8 and 9

Table 8

Effect Size Differences in Performances in Different Domains
Between Non-STS and STS Students in Different Courses

Study Number/Population	N	Concept	Process	Application	Attitude	Creativity
2 Elementary	5	0.00	2.57	3.03	1.70	3.23
2 Middle	5	0.00	3.20	3.63	1.79	1.91
2 Junior High	5	0.00	2.26	4.30	1.55	1.96
3 Ninth Grade	2	0.05	0.35	0.66	0.55	3.00
4 Taiwan Student Teachers	2	0.04	0.67*	0.75	0.89	0.31

* Understanding the Processes of Science